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SOME DISTINCTIONS IN OUR CULTIVATED BARLEYS WITH REFERENCE TO THEIR USE IN PLANT BREEDING.

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INTRODUCTION.

When the writer began active operations in barley breeding in 1909, the intelligent selection of mother plants was found to be very difficult because of the lack of sufficient information to enable minor variations to be recognized and interpreted. European breeders had subjected the taxonomic details to a most exacting scrutiny, but their results were not immediately useful. It was necessary to confirm the European findings, for a character found stable there could not be considered stable under the widely varying climatic conditions of America until it had been so proved. Again, the European authorities were far from united. There was not even a broad taxonomic character whose stability had not been questioned at one time or another, and often by the highest authorities in barley classification. Moreover, even if the groundwork could have been adopted entire, the more or less established taxonomic characters are only the beginning of the problem. Breeding must take note of characters that are trivial in taxonomy. The intangible must be analyzed and made to serve, as well as the tangible.

Even the very plausible idea of adopting European methods and importing improved European stocks was only partially successful. Conditions in America differ in one vital particular from conditions in Europe. On the Continent and in Great Britain barley has been cultivated for centuries, and it is therefore practically indigenous. Each geographical locality has, through long periods of time, been provided by natural selection and acclimatization with superior native races. Breeding, under such conditions, is largely concerned with the improvement of these existing stocks, with small likelihood of any importation proving to be a serious competitor.

NOTE.—A large part of the data herein presented was obtained in cooperation with the Minnesota Agricultural Experiment Station, and the article itself was submitted as a thesis as required for the degree of doctor of science in the University of Minnesota. The subject is of interest to plant breeders and agronomists.

In America there are no native stocks. The grain-producing areas are relatively new. The varieties peculiar to a section are usually the result of chance introductions. Breeding material from foreign sources is as likely to contain desirable types as is that already at hand. In this investigation, in order to obtain the proper basis upon which to conduct breeding work, stocks were assembled not only from local sources but from all over the world. Many distinct strains were isolated from each stock, for both the local varieties and the foreign introductions were usually either races that had not been purified or that had become mixed after purification. The isolation was accomplished by head and plant selections, which when grown in pedigree rows formed a surprisingly large collection. When to these were added a still greater number from the progeny of hybrids, the problem became one of elimination. The plant selections from their very nature were made more or less arbitrarily, and hundreds of these forms were necessarily duplicates. These duplicates, especially as long as they were not so recognized, were a drain upon the breeder, and it was soon realized that the efficiency of a nursery was measured, not by the number of stocks it carried but by the number it eliminated.

It was to accomplish this reduction better that the character studies were made. The distinctions found were of two classes, morphological and physiological. The morphological variations were, in the broader divisions, of taxonomic value, and many of them were practically invariable. The physiological characters were, from their nature, more difficult to appraise. They were found to possess not only more widely fluctuating limits, but the limits often overlapped and at times the characters became inseparable. In physiological characters a further distinction was made between permanent and place variations. Some separations were so wide that they never became confusing, while others became evident only when grown under certain conditions of soil and climate. Such distinctions are worthless as taxonomic features, but have proved very valuable as indications of individual qualities in breeding. Even the lack of stability in a character does not destroy its usefulness, as the tendency of a strain to behave in a certain manner under certain conditions may mark an inherent difference.

It is realized that distinctions of this kind are only a part of plant breeding, and it is not thought that that part is clarified in any great measure. In this paper are given a few of the observations that have been found useful in barley breeding, and with them many that have been found useless. The data upon which the conclusions are based consist of some 200,000 recorded observations, extending over a period of five seasons and embracing experiments at St. Paul, Minn.; Williston and Dickinson, N. Dak.; Highmore, S. Dak.; Moc-

casin, Mont.; Aberdeen and Gooding, Idaho; and Chico, Cal. Of the work done at these points, that at St. Paul, Minn., which was conducted in cooperation with the State experiment station, was the most extensive.

REVIEW OF THE LITERATURE.

Although the literature of barley is, with the possible exception of wheat, more extensive than that of any other cereal crop, the publications bearing directly upon the theme of this paper are comparatively few. The great mass of the European publications, especially the German ones, have to do with the malting quality of barley. They are concerned mostly with its chemical constituents, the effect of soil, climate, and culture upon the nature and composition of the grain, and the behavior of the converting enzyms in grains of different character. The same is true of papers on the morphology of the grain, and even many of the publications treating directly of barley breeding have little bearing upon the present discussion, as they are often concerned only with the correlation of characters or with the behavior of hybrids. It is only the papers dealing with the taxonomic features of barley, and experiments such as those of the Swedish Plant-Breeding Association at Svalof, which have had for their end the isolation of plant variants, that are of particular pertinence.

The first comprehensive systematic work was that of Körnicke (15)[1], who described 44 botanical forms of barley, using spikelet fertility, color, nature of the awn and glume, and the adherence or nonadherence of the palea. His groups will undoubtedly form the bases of all future classifications. The classification of Voss (25) is important largely because he based a part of it upon the extent of overlapping of the grains, thus forecasting in an indefinite way the use of density. Atterberg (2) made use of the bristle and nerve characters discovered by Neergaard, mentioned below, and subdivided the previous groups until he had 188 named botanical varieties. Beaven (3), by a rearrangement and compilation of previous classifications and by growing and describing a large number of hybrids of Karl Hansen, Körnicke, and others, gave a very clear conception of the entire species. His work is perhaps most valuable in the placing of the Abyssinian forms with abortive lateral florets in a group by themselves. He does not make use of the finer subdivisions employed by Atterberg. Regel (21), on the contrary, carries the subdivision still farther and uses twisting of the spike and earliness and lateness of the variety in his separations. The last, a purely physiological phase, he employs in named botanical forms.

A review of the work at Svalof is especially valuable in this connection because of the fact that a large part of that effort has been

[1] The figures in parentheses refer to the bibliography at the end of the bulletin.

along the same line and because, in many instances, this investigation has merely attempted to discover whether results obtained by them were sustained under the great variations of the American climate. In barley the greatest achievement at Svalof was the discovery of two kernel characters, which, by various combinations, gave four separations under each previous group.

These investigators found that the rachilla in some barleys was covered with long straight hairs and in others with short curly ones; also that the inner pair of dorsal nerves sometimes bore teeth and were sometimes smooth. The stability of these characters was questioned by Broili (10), who claimed to have frequently observed one form in the progeny of another. Tschermak (13), Blaringhem (7), and others have supported the investigators of the Plant-Breeding Association at Svalof, at least so far as the basal bristle is concerned. Although none are to be compared with this discovery in importance, many other studies have been made at Svalof. At one time they had developed a very elaborate system of measurements made by means of many ingenious mechanical devices. They have, unfortunately, made no specific, comprehensive publication of their negative results, but according to Newman (20) and others they have abandoned the use of many of the measurements that were formerly made. Of those retained, the most important from the standpoint of this paper is that of density. In the early history of the association two or three varieties were obtained by the "élite" method. They chose an arbitrary density and made mass selections of spikes conforming to that measurement. Later, they used density as a means of valuing head measurements, as a long head if loose might contain no more grains than a short one if compact. They finally employed it in varietal description. Blaringhem (7), who has followed the work of the Svalof association quite closely, used density as an indication of purity and to reveal the effect of climate.

The morphological characters of the seed coat and the kernel have been treated by Kudelka (16) and Johannsen (14), but there is no suggestion of usable varietal differences.

The composition of the grain has been studied by a few American and a large number of European scientists. Le Clerc and Wahl (17), who have made the most comprehensive of the American studies, have clearly demonstrated that composition is of slight use as a varietal character for, while there are differences, the effect of location and season is many times greater than that of variety.

Color in barley has been employed by all systematists, but has received very little analytical attention. Brown (11) has a note on the color in the variety *coerulescens*, and numerous authors have discussed the occurrence of pigments in other plants. A recent article by Wheldale (26) treats of the chemical nature of anthocyanin and traces its origin from a glucosid.

THE RATE OF DEVELOPMENT.

The rate of development, like all physiological characters, is subject to considerable fluctuation within the strain. The distinctions are naturally much less absolute than those founded upon morphological characters. They have, however, the advantage that they permit a greater number of separations. A plant structure usually has but two phases. It exists or it does not exist. With physiological characters this is not the case. The length of time required for one variety to mature may differ three days from that of a second or it may differ three weeks. From the standpoint of observation, the development of the plant is divided into three periods: (1) The early development from germination to the time of jointing, (2) the period of heading, and (3) the period of maturity.

EARLY DEVELOPMENT.

For some time the writer has maintained that the early growth is the stage of development at which selections of barley are most easily distinguishable. This period seems to have been neglected by plant breeders. There are few records of notes taken during this time, and even those breeders who have known the cereal crops best have based their selections at this period on an intangible something that enabled them to single out any new variation.

During the summer of 1913 an attempt was made to analyze the intangible, with most encouraging results. In addition to careful observations on several hundred selections, 1,400 plants were chosen in the nursery and 1,700 in drill rows, upon which exact records were kept. One hundred plants were used in each variety. The data included the day upon which each of the 3,100 plants produced its second, third, and fourth leaves and its first tiller. The optically plausible became mathematically evident, and it was soon seen that, aside from the leaf character, there was ample justification for the separations made on appearance during the early stages of growth. As figure 1 shows, the selections rush through the early stages at an astonishing rate. A centgener which is only two days, or even one day, behind a second may be in an entirely different stage of development and may therefore present an appearance which in no way resembles that of the first. Yet the two barleys may be closely related strains and inseparable or separated with difficulty at maturity. The typical curves of the production of the second, third, and fourth leaves are always very sharp. In figure 1 the curve of tillering is more flat than is usually the case. The first of the third leaves emerges about the time of the appearance of the last of the second. The fourth leaf is produced in about the same relation to the third, but perhaps a little earlier. The first tillers are usually simultaneous with the fourth leaves, though in some varieties they appear earlier.

The tillering in most varieties is not completed as rapidly as is the production of the fourth leaf, and it is deterred by disease much more than is the leaf.

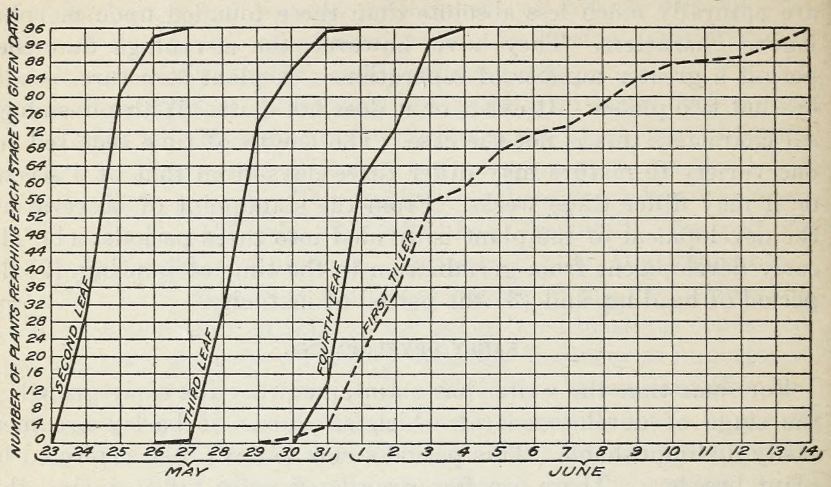

FIG. 1.—Curves showing the production of the second, third, and fourth leaves and of the first tiller in 96 plants of Oderbrucker barley (selection No. 50).

Besides the difference in dates there is a difference in method of production. In some varieties the curve of each stage is very acute and the stage is completed in a few days. In others it is more obtuse

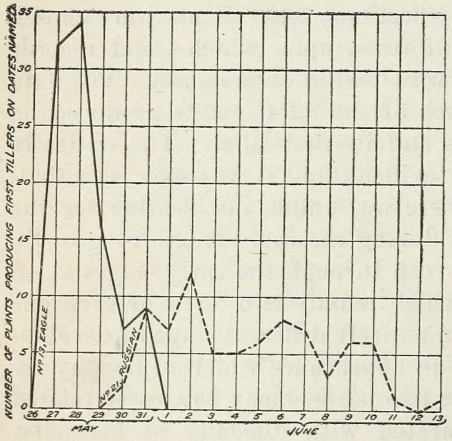

FIG. 2.—Curves showing varietal differences in the rapidity of tillering of barley selections. In Eagle (No. 13) all plants produce tillers almost simultaneously, while in Russian (No. 21) the process is extended over many days.

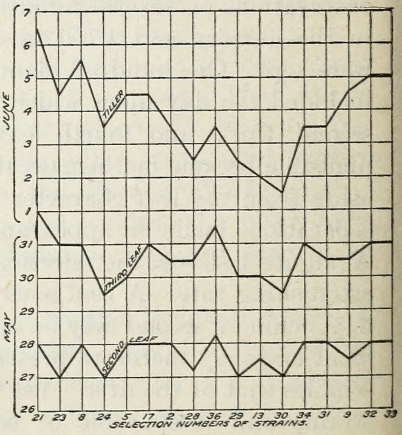

FIG. 3.—Curves showing the average date of the production of the second and third leaves and of the first tiller in 100 plants of each of 17 selections of barley grown in drill rows.

and the time for completion extended. Figure 2 shows the relative rapidity of stooling in two selections, the one of the first type and the other of the second.

Differences are revealed in two ways by a comparison of the behavior of strains. There is an actual difference of date in any stage and, still more important, a relative difference between various stages. This is shown to some degree in figure 3, and to a still greater degree in figure 7, which will be discussed later. Figure 3 shows the date upon which the greatest number of plants in 17 selections sown in drill rows reached the three stages of development. It will be noticed that the average date of the occurrence of the second leaf varied over scarcely more than 1 day, while the third extends over 2½ days, and the production of tillers over 5 days. No. 5, for instance, produces the third leaf 2 days after the second, while No. 13 requires another half day. Yet No. 13 requires but 3 additional days to produce tillers, while No. 5 requires 5½ days.

EMERGENCE OF THE AWNS.

The time of heading is a general agronomic note, and there is no doubt that an observation of this period is of great value in plant breeding. Distinctions at this time should be easily made and should be more reliable than those of any later date. The difference between selections is greater than in the earlier stages, and the effect of season is not apparent in any abnormal hastening of development, as it is later in ripening. In any climate, most barleys develop in a fairly normal manner until flowering time. The time of heading, for these reasons, should be of great use. It has, however, one disadvantage. It is an extremely difficult note to obtain, and hence inaccurate. Barleys differ very much in their manner of heading. Some heads are exserted rapidly and completely, others slowly and only partially. The observer has not only the difficulty of maintaining an arbitrary mental standard, but is confronted by numerous exceptions that never conform to any standard.

In a study of this difficulty it was noticed that just previous to heading, the tips of the awns in all awned varieties projected from the boot of all plants in the selection with suggestive uniformity. The date of the emergence of the awns was substituted for the date of heading, with excellent results. The personal error was immediately removed and, as the facts could be gathered at a glance, the note taking was greatly accelerated. The change made a valuable plant-breeding observation out of a dubious agronomic note.

Analyzed, the curve of date of emergence of the awns is almost as sharp as those representing the production of the leaves and tillers. Figure 4 shows the curve of 13,108 plants, a summary of the observations of a large number of selections. It will be noticed that nearly two-thirds of the plants pass through this stage in two days. A difference of a single day serves to change the appearance

of a whole centgener, and strains that are three days apart are unbelievably dissimilar when viewed at this time.

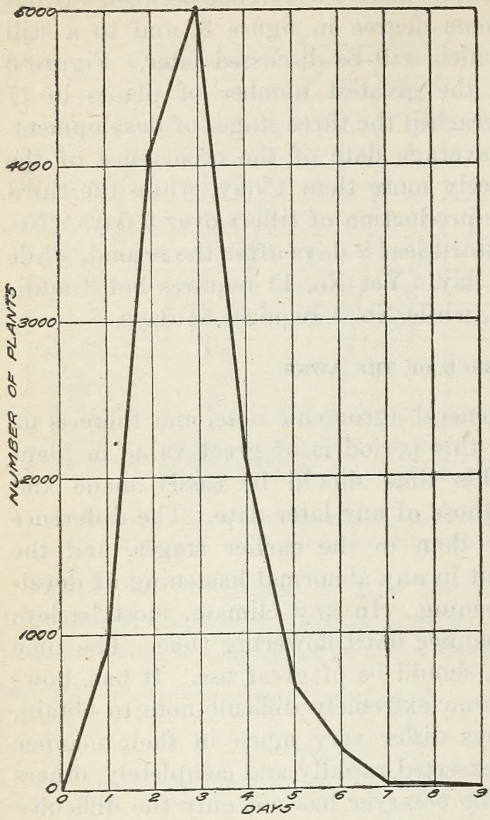

FIG. 4.—Curve showing summary of data on the emergence of the awns in 13,108 plants from various selections of barley.

This note was taken for a large number of selections for three years to test the transmissions of slight variations in earliness and lateness. The evidence seemed all in favor of accrediting to this character a heritability equal to that of most plant characters. The data are too cumbersome to include entire, but a random selection of strains of one general type is given in figure 5. The variations are parallel, on the whole, especially when it is remembered that the centgeners were often separated by considerable distances, allowing variations in soil and moisture. The exceptions are fully as likely to represent differences in the character of the strains, causing them to respond differently to different seasons, as they are to question the value of the note.

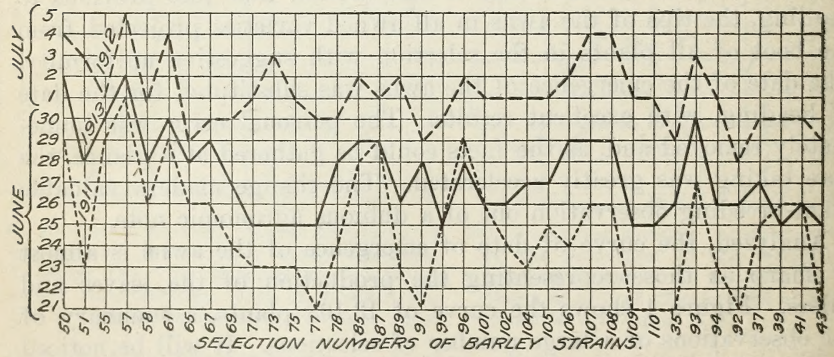

FIG. 5.—Curve showing the effect of season upon the relative date of the emergence of the awns in 37 selections of 6-rowed barley grown at St. Paul, Minn., in 1911, 1912, and 1913.

DATE OF RIPENING.

The date of ripening is a note universally taken. While less dependable than the emergence of the awns, it is a very useful observation. Within a strain the plants mature quite uniformly. In order to determine the amount of such variation, the exact date of maturity of each spike in a plat of Manchuria barley was recorded. The spikes were considered ripe when the last traces of green disappeared from the glumes. In order to avoid confusion, they were harvested as fast as they ripened. The result is shown in figure 6. The curve is very sharp, almost half the product of the plat maturing upon the same day.

The weakness of the note is in the abnormal ripening of varieties. In Minnesota the observation is quite dependable in Manchuria forms, but is likely to be much less so in the 2-rowed varieties. Some of the latter mature in a normal manner, while others, especially the later ones, half ripen and half die. Also, a rain at this period has much more influence in the development than at other times in the life of the plant.

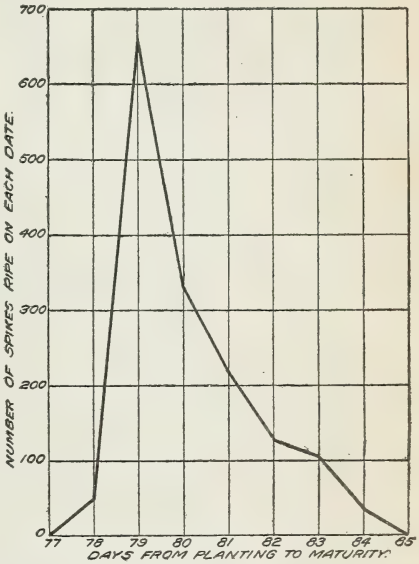

FIG. 6.—Curve showing the ripening of 1,541 spikes in a plat of Manchuria barley, stated in days from date of planting.

COMPARATIVE RATES OF DEVELOPMENT.

Although separations can be made by a study of any one of these stages, it is only when the entire seasonal histories of the selections are compared that the full variation is apparent. Figure 7 shows the development of 14 strains from the production of the second leaf until maturity. Each stage was obtained by actual count of all the normal plants in each centgener, usually between 90 and 100.

The relation of the earlier stages has already been commented upon. It will be noticed that the tillers are produced usually after the fourth leaves. In Nos. 34, 13, and 24 this is not the case, and these three selections are definitely distinct from the other eleven by this different habit of tillering. Nos. 21 and 57 are parallel in the earlier stages but are widely separated in the emergence of the awn. No. 29 is one of the earliest of all the selections to produce the second leaf,

and yet it is among the very latest in maturity. Indeed, there is some peculiarity about each one of the fourteen when all stages are considered.

VARIATIONS IN THE CULM.

The culm varies in length, diameter, thickness of walls, exsertion of spike, number of nodes, and number of culms per plant.

LENGTH OF THE CULMS.

The height of the plant is a note universally taken on all experimental farms. At any chosen station, some varieties are always tall and others always short. This distinction is sufficient to prove a difference between such varieties, and as such it is a useful observation in breeding. It is, however, merely a proof that a difference exists and is not necessarily a difference in itself. There is a physiological adaptation of varieties to certain places and it may express itself in height.

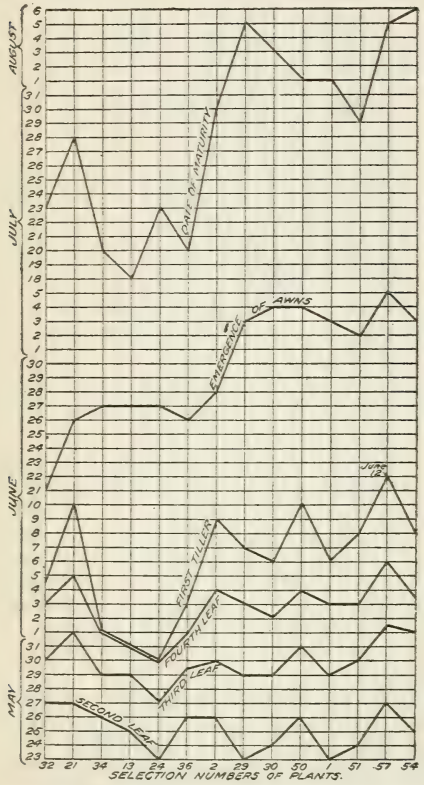

FIG. 7.—Curves showing the date of the production of the second, third, and fourth leaves and the first tiller, the emergence of the awns, and the day of ripening in 14 selections of barley grown at St. Paul, Minn., in 1913. Each determination was based on one centgener of approximately 100 plants.

In 1911 thirteen pedigreed selections, representing nine minor groups of barley, were chosen from the nursery stock and planted at four widely separated points. At maturity the length of culm was carefully noted. The influence of climate and soil was surprisingly great. As will be seen in Table I, there is a marked regional response. The selection of Odessa is a *Hordeum sativum hexastichum* form occurring in the commercial Odessa variety. In Minnesota it is short and unpromising. In California it is little better, while in the north Rocky Mountain and Plains areas it displays an unexpected vigor and is very tall. The Abyssinian varieties grow well in California, but are short elsewhere.

TABLE I.—*Influence of geographical location on the length of the culm in 13 representative selections of barley grown at four widely separated points, the selections being arranged in the order of their height at each point.*

St. Paul, Minn.	Williston, N. Dak.	Moccasin, Mont.	Chico, Cal.
Hordeum vulgare	Servian	Odessa	S. P. I. No. 20375.
Oderbrucker	Odessa	Hordeum vulgare	Oderbrucker.
Manchuria	Hordeum vulgare	Surprise	Abyssinian.
Summit	Smyrna	Summit	Servian.
Princess	Oderbrucker	Servian	Smyrna.
Surprise	Manchuria	S. P. I. No. 20375	Manchuria.
Servian	Summit	Kitzing, 6-rowed	Summit.
S. P. I. No. 20375	Surprise	Manchuria	Odessa.
Kitzing, 2-rowed	Kitzing, 6-rowed	Oderbrucker	Kitzing, 6-rowed.
Kitzing, 6-rowed	S. P. I. No. 20375	Smyrna	Princess.
Abyssinian	Princess	Abyssinian	Kitzing, 2-rowed.
Smyrna	Abyssinian	Kitzing, 2-rowed	Surprise.
Odessa	Kitzing, 2-rowed	Princess	Hordeum vulgare.

The great variation evidenced by these few selections is sufficient to show that the length of culm can not be of much taxonomic value. There are varieties which are persistently below average height, and others that are as persistently above, but beyond that it is difficult to make an unqualified statement. Locally, this measurement is of more significance and can often be used to advantage in the study of nursery selections. The differences it reveals are important in breeding, no matter to what cause they may be due.

DIAMETER OF THE CULMS.

Measurements have not been found very useful in revealing small differences in the diameter of the culm. The experimental error is large, owing to the fact that the diameter varies on the same plant with the culm selected, on the same culm with the internode chosen, and on the same internode with the distance from the node. A part of this variation was avoided by measuring the greatest diameter of the first elongated internode, but even then the results were unsatisfactory. There are varietal differences, but they must be great enough to be seen optically before the error of measurement is reduced to the point where it becomes negligible. As a group, the *nutans* has smaller culms than the Manchuria, but among the Manchuria strains there is little difference. Only once in these investigations has this character been used to isolate a type. This type has proved to be stable, and perhaps the effort of measuring hundreds of selections is rewarded by the one strain obtained, as it is very promising.

THICKNESS OF CULM WALLS.

A large number of determinations were made of the thickness of the walls of the culm, with even less satisfaction than in those of the diameter. Measurements finer than one-tenth of a millimeter are impracticable, owing to the variation within the plant and culm. This does not give range enough to disperse the varieties. For in-

stance, of 242 selections of 6-rowed barley, the culms of 153 measured 0.5 mm. in thickness and only 33 deviated more than 0.1 mm. from this figure.

THE EXSERTION OF THE SPIKE.

The exsertion of the spike is closely related to the length of culm because it depends upon the elongation of the peduncle. Some barleys clear the boot much more completely than others. That this is a true varietal character is shown by the number of varieties in which it has been described. The Princess in Sweden is often included at the base. The same is true of this variety in Minnesota and California. The Smyrna seldom clears the boot completely in more than one or two culms on each plant. An interesting fact was noted in this variety with reference to location. In Minnesota, half the head often remains in the boot, and the same condition prevails over the whole of the Plains area. In California, however, the heads are completely exserted. The exsertion is still short as compared with most varieties, but it is perfect. Like other physiological characters, the exsertion of the spike is variable, but its range of variation is sufficiently limited to occasionally determine a variety. That it is not more often useful is due to the fact that almost all barleys are of the type in which the spike is completely exserted.

NUMBER OF NODES PER CULM.

The number of nodes to the culm is naturally identical with the number of leaves to the culm and is discussed under that heading.

NUMBER OF CULMS PER PLANT.

The number of culms per plant seems to be a varietal character, but one which is so dominated by environment as to make it impossible to determine when it is given true expression. It is probable that all students of the cereals have gone through the same process of diminishing confidence to final doubt as to the utility of this factor. In this investigation the number of tillers was recorded on over 20,000 plants without being able to discover a method of using such information for minor distinctions, as was possible, for instance, with the time and method of tillering. The broad groups vary as groups in this character and occasionally a variety deviates sufficiently from its group to become distinct, but the mass is, for the most part, inseparable.

Two causes of variation were studied in detail, viz, spacing and geographical location. In Minnesota a selection of Smyrna, a heavy-tillering variety of a 2-rowed group, and a light-tillering selection of Manchuria of the 6-rowed group were planted at three different spacings. The results obtained are shown in Table II. As will be

seen in this table, the varieties remained distinct in their tillering habit, but as the space decreased, the difference of over three culms per plant in favor of Smyrna rapidly diminished to one. Types falling between these extremes were inseparable at the least spacing. It will also be noticed that the varieties differ in the spacing at which they seem to make complete use of the soil. An increase in number of plants in the Manchuria beyond the 4 by 4 inch plantings does not increase the number of tillers on the unit area, while for Smyrna the limit is not yet reached.

TABLE II.—*Effect of interval on the production of culms in selections of Smyrna and Manchuria*[1] *barley.*

Plants and culms.	Space between plants.					
	4 by 8 inches.		4 by 4 inches.		4 by 2 inches.	
	Manchuria.	Smyrna.	Manchuria.	Smyrna.	Manchuria.	Smyrna.
Total plants	42	46	87	80	179	190
Total culms	122	282	234	361	236	446
Culms per plant	2.9	6.1	2.7	4.5	1.3	2.3

[1] The selection of Manchuria was made for its low-tillering habit, and it is not typical of the Manchuria variety as commonly grown.

The response to geographical location is a disturbance sufficient to vitiate all close distinction. Even the groups are often reversed. For instance, when summarized, a large number of selections of 6-rowed barley at St. Paul averaged 2.6 culms per plant, while at Chico the same selections averaged but 1.5. The 2-rowed group, on the contrary, averaged but 4.2 culms at St. Paul, while at Chico it averaged 5.8. The Smyrna, however, stood near the top in both places, showing that in extreme cases the effect of environment does not conceal the character.

LEAF CHARACTERS.

The leaves of mature barley plants present quite a variety of aspects which are, as a whole, hard to record. Most of them are mass effects, and hence treacherous, because of the optical differences due to the angle of observation with reference to the light. This investigation is concerned with four points of variance—the color, the width, the length, and the number of leaves.

COLOR OF LEAVES.

A very casual observation shows a considerable difference in the color of leaves, but there are so many difficulties in their valuation that the writer is unprepared to discuss their separation at this time.

WIDTH AND LENGTH OF LEAVES.

Any study of leaf dimensions must be statistical and therefore difficult to report briefly. The obstacles to the use of such measurements are twofold: The leaf varies with its nourishment and with its exposure, and it is often damaged by the wind. In a study of mature plants, the second leaf from the top being used in all cases, the normal variation was found to be considerable. For instance, at the same place in the same season the leaves of border plants were from 1 to 2 mm. greater in width than those from the interior of the plat, and the length of the leaves of such plants was from 2 to 3 cm. greater. In Princess, one of the least variable varieties, the average size of the leaves of the border plants was 13.7 mm. by 24 cm., and of the interior plants 12.7 mm. by 23 cm.

To be usable in breeding, a note must be reasonably easy to obtain. To test the usefulness of this character, the first 25 of the 100 measurements of each selection were tabulated, as shown in Table III. With width of leaf, the experimental error is small, as width can be determined quite accurately and the broadest part of the leaf is seldom damaged. If the figures, then, are conclusive mathematically, the method is practical. The probable error in the 25 measurements of Princess is ± 1.2. It thus fails to separate this variety dependably from Kitzing and Proskowetz, its nearest relatives, or from the selection of *deficiens*, or Odessa. (See Table III.) From the rest, however, the separation is clear enough to be significant. With the two selections of Oderbrucker, the separation is sufficient to establish a difference. In this case the two are closely related and the note becomes serviceable. As a rule, the width of leaf is seldom a sufficient basis for separation in closely related strains. Fortunately, such differences are seldom unaccompanied by other points of variance, and it is often the sum of several differences that serves to distinguish individual strains.

TABLE III.—*Greatest, least, and average width and length of 25 leaves in each of 13 selections of barley grown at St. Paul, Minn., in 1911.*

Pedigreed selection from—	Leaf width.			Leaf length.		
	Greatest.	Least.	Average.	Greatest.	Least.	Average.
	Mm.	*Mm.*	*Mm.*	*Cm.*	*Cm.*	*Cm.*
Princess	15.0	12.5	13.2	28	20.0	23.5
Kitzing, 2-rowed	15.5	11.0	12.7	28	20.0	23.7
Hordeum sativum deficiens	16.0	12.5	13.7	32	26.0	28.7
Oderbrucker	17.5	14.0	15.5	23	17.0	19.2
Manchuria	20.0	14.0	16.7	27	18.0	22.8
Oderbrucker	22.0	15.0	18.7	28	20.0	24.3
Summit	15.5	12.5	14.3	26	18.0	22.5
Kitzing, 6-rowed	20.0	16.5	18.5	26	18.0	22.6
Surprise	20.0	16.5	18.3	26	19.5	22.9
Servian	20.0	15.5	17.8	25	20.0	22.8
Odessa	15.0	11.0	13.7	22	14.0	17.9
Abyssinian	22.0	17.0	18.7	25	20.0	22.0
Proskowetz	16.0	11.0	13.0	28	23.0	25.5

In length of leaf, the method is much less promising. Not only is the probable error greater, but the measurement is unsatisfactory. The leaves become so broken by whipping in the wind that specimens which are entire at the tip are seldom found. An effort was

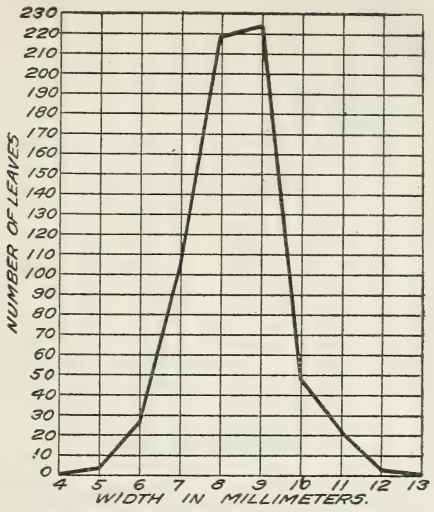

FIG. 8.—Composite curve showing the width of leaves in millimeters in eight selections of barley.

made to overcome this difficulty by choosing an earlier stage of development and thus utilizing the better protected leaves nearer the ground. Although the extreme tendencies were not yet developed, the second leaf from the seedling was found to offer fewer experimental difficulties. Such leaves were entire and the length

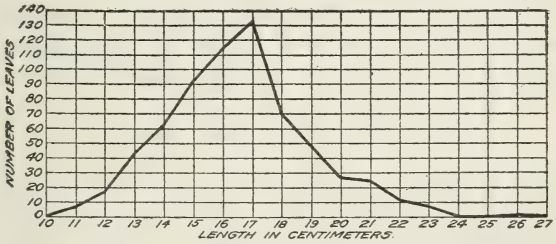

FIG. 9.—Composite curve showing the length of leaves in centimeters in six selections of barley.

measurements accurate, but even then the width was much less variable than the length. All measurements, consisting of 100 leaves of each strain, showed a sharp curve in width, but a flat one in length, the latter sometimes having two summits. Composite curves are shown in figures 8 and 9.

The summary of leaf measurements of 316 pedigreed selections in Table IV shows that the common taxonomic groups, based upon spike characters, are correlated in the nature of their leaf growth.

TABLE IV.—*Summary of measurements of the width and length of barley leaves made at St. Paul, Minn., in 1911, arranged according to the common taxonomic groups.*

Group.	Number of strains.	Leaf width.			Leaf length.		
		Greatest.	Least.	Average.	Greatest.	Least.	Average.
		Mm.	*Mm.*	*Mm.*	*Cm.*	*Cm.*	*Cm.*
Hordeum sativum erectum	11	17	13	14.0	26	22	23.9
Hordeum sativum nutans:							
Long-haired	67	14	9	11.4	27	20	23.0
Short-haired	18	18	10	13.6	28	20	24.2
Hordeum sativum vulgare:							
Manchuria types—							
Long-haired	49	18	13	16.1	25	20	22.6
Short-haired, white	85	20	15	17.7	26	22	23.7
Short-haired, blue aleuron	34	19	14	16.8	25	21	23.3
Russian types	23	19	13	17.0	27	22	23.7
Hordeum sativum hexastichum	29	19	10	15.4	26	19	22.2

NUMBER OF LEAVES.

The number of leaves, excluding, of course, those formed before the appearance of the shoots, is the same note as the number of elongated internodes in the culm. The number of leaves above the basal rosette is a variable, but at the same time rarely a useful distinction in breeding. Strains may be found which are very different, but usually they are not closely related. Thus, in the variety Hannchen the number often drops to three and seldom goes above five. In the selection of *Hordeum sativum hexastichum* the number rarely falls as low as five and is usually six or seven. This distinction, however, is not necessary to separate these forms. In each of several hundred Manchuria selections the number of leaves per culm fell upon either four or five, giving no opportunity for separation.

THE DENSITY OF THE SPIKE.

The writer is inclined to place even more importance upon the density of the spike than has been the tendency of many barley breeders. Aside from its finer distinctions, some of the effects attributed to other characters are in reality due to the length of the internode of the rachis. Most investigators have attributed the difference between *Hordeum sativum vulgare* (*tetrastichum*) and *Hordeum sativum hexastichum* to a difference in fertility. They have considered that in *Hordeum sativum vulgare* the side florets are more reduced than in *Hordeum sativum hexastichum*. This supposition is not borne out by the facts. In the *Hordeum sativum hexastichum* the central row is as favored in nutrition as it is in the *Hordeum sativum*

vulgare. This is easily demonstrated by weighing kernels from side and central spikelets. In the *Hordeum sativum vulgare* the lateral kernels, compared with the central ones, are actually greater in relative weight than is the case in the *Hordeum sativum hexastichum*.

Differences other than density are likely to be due to the nature of the attachment of the lateral spikelets. Systematists describe the barley spikelets as sessile. This is true in most cases, but it approaches an exception in *Hordeum sativum hexastichum*. In this group the central spikelets are sessile as usual, but the lateral ones either possess an elongation of the base of the flowering glumes or else are pedicellate. Among the barleys collected by the writer is a Greek form in which the lateral spikelets are elevated upon a pedicel that is over one-half as long as the length of the rachis internode itself. This pedicel is jointed both at its attachment to the rachis and at its attachment to the floret. It is the longer attachment of the lateral spikelets that allows the characteristic radial arrangement of *Hordeum sativum hexastichum*. Density is, however, a parallel factor. The compactness of the spike forces the kernels to assume certain relations. Both in *Hordeum sativum hexastichum* and in *Hordeum sativum erectum*, the kernels are placed at a much wider angle with reference to the rachis than in *Hordeum sativum vulgare* and *Hordeum sativum nutans*. The Swedish Plant-Breeding Association at Svalof has considered the angle of the inclination of the kernels as one of the more important of their notes. It is the opinion of the writer, however, that, with rare exceptions, it will vary directly with the density, and is therefore superfluous if the latter measurements be taken.

In breeding, density has not been utilized as fully as its value seems to warrant. Voss (25), Körnicke (15), and Atterberg (2), have used it in group classification, and Atterberg, Blaringhem (8), and the breeders at the Svalof station have used it in studies of variation and purity, but in the opinion of the writer its possibilities in the isolation of types and in the identification of strains have been far from exhausted.

In the years from 1909 to 1913 a close study of density was made, both upon general farms and in experiment-station nurseries. In this study, 100 spikes of each variety were taken without other choice than that they were not diseased or dwarfed. On each of these spikes 10 internodes of the rachis were measured; that is, the distance was between six spikelets on one side of the rachis. From these measurements the number of internodes per decimeter was computed and this number taken as the unit of density. The formula was then $D=1{,}000 \div L$, where L was the length in millimeters of 10 internodes of the rachis.

The use of this formula, while it makes the statement of density more definite, disturbs the natural curve of the measurements to some extent. In all densities below 31 the tendency is to condense the grouping; above that figure the opposite is true. The worst effect—that of bunching the figures when two-length measurements fall upon the same density—was avoided by the use of fractions. None of the curves have been smoothed, however, and it will be noticed that those of the greater densities, especially, are slightly rough. This roughness is more mathematical than real, but it seemed more desirable to present the figures as they were than to make them still more artificial by smoothing them.

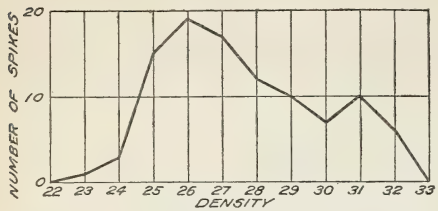

FIG. 10.—Curve showing the density (number of internodes in 1 decimeter) of 100 spikes of Manchuria barley from a field near Excelsior, Minn.

In a pedigreed strain the curve of density is normally sharp, with a single summit. If the seeding is not pure, or if the heads from two plats become mixed, the curve is flattened and is characterized by more than one summit. Although included for another reason, the normal curve of a pedigreed barley is well illustrated in figure 12. When this is compared with the curve of the field sample of Manchuria shown in figure 10, the significance of density is readily appreciated, especially when it is remembered that the Manchuria is what is known as a variety and contains no types that merge into such other 6-rowed varieties as Bay Brewing or Odessa.

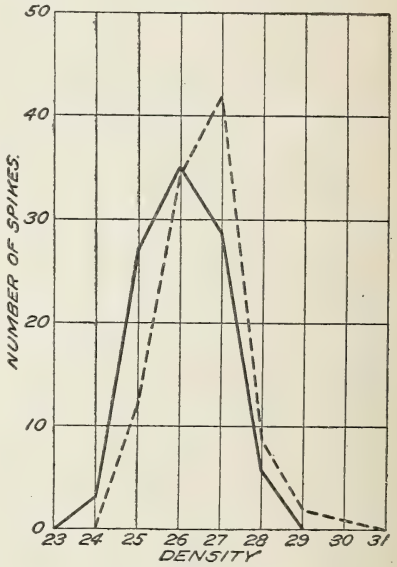

FIG. 11.—Curves showing the density of 100 spikes from two plats of Sandrel (No. 35) barley planted in different parts of the 1913 nursery at St. Paul, Minn.

That density of selections is an accurate and comparable note in a nursery where the object is to obtain like conditions for all selections is shown in figure 11. The Sandrel was included twice in the 1913 planting. The beds were separated by such a distance as to represent the extremes of soil variation in the nursery. The difference in density is very slight.

The summits of the curves are separated by only one unit of density, but even this is seen to be too great when the entire curves are considered. Although the second summit is on 27, there are 46 spikes whose density is less than that number and only 12 whose density is greater. The actual separation is nearer five-tenths of a unit. The degree of separation afforded by a difference of only two internodes to the decimeter is shown in figure 12. These are two selections of Manchuria barley taken at random from Table V. By chance, they are somewhat more ideal than the average strain in the same table. A difference of only two units in density, when taken alone, is perhaps too slight a basis upon which to separate strains, yet, as is shown in the figure, the field of actual merging is very small.

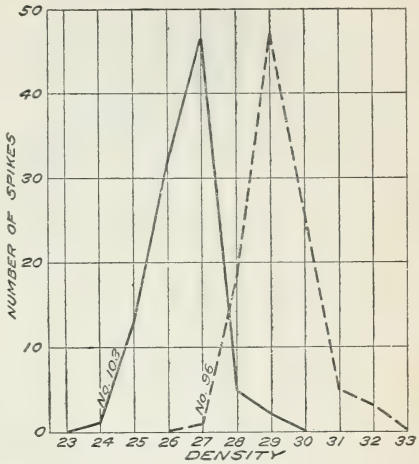

FIG. 12.—Curves showing the density of 100 spikes from two selections of Manchuria barley grown at St. Paul, Minn., in 1913.

The value of this character in the nursery is shown in figure 13. These barleys are all closely related pedigreed strains of Manchuria. Most of them were from head selections made upon farms in southeastern Minnesota. The curve represents the summits of the curves of densities of the individual selections. The variation is considerable and is sufficient to establish some differences of itself. It is, however, only when several characters are compared that the full value of any note is apparent. For this purpose, the date of the emergence of the awn is placed also in figure 13. As they are in no way parallel, the combination of the two curves more than doubles the value of each. It will be noticed that Nos. 3, 6, and 55 are suspiciously similar, the density and the date of emer-

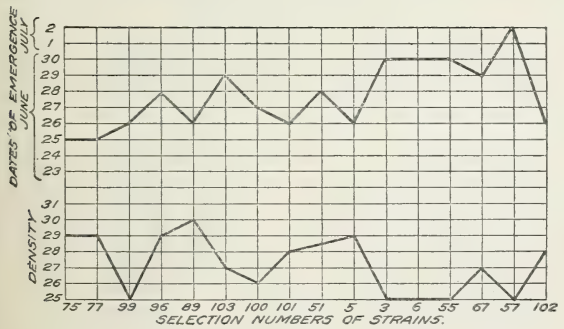

FIG. 13.—Curves showing the average density and the date of emergence of the awns in 16 selections of Manchuria barley grown at St. Paul, Minn., in 1913.

gence of the awns of the three being identical. The records show that the emergence was also on the same date the previous year. No. 55 is proved to be distinct by the nature of the rachilla, but the date of heading, time of stooling, etc., are parallel in Nos. 3 and 6, and there is little doubt that they are identical.

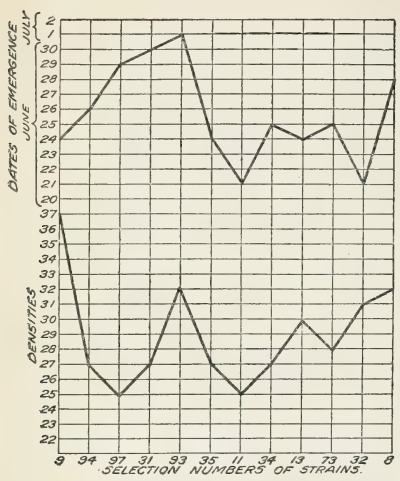

FIG. 14.—Curves showing the average density and the date of emergence of the awns in 12 miscellaneous selections of barley grown at St. Paul, Minn., in 1913.

While not pertinent to this phase of the discussion, the curve of density and the curve of emergence of beards are almost opposite in the Manchuria barley. In other words, there seems to be a direct correlation between density and earliness. In figure 14, in which are assembled a number of other types of 6-rowed barleys that are for the most part not closely related, this is not true.

The first five selections, the densities of which are shown in figure 14, are from a commercial variety known as Odessa. This so-called variety seems to be a loose assemblage of widely varying types, which are, however, ones not common in other 6-rowed barleys. The component strains are not nearly as closely related as are those of the Manchuria. That this variety itself is of hybrid origin or that there has been crossing between its members is indicated in figure 15. This selection, the most dense of those made from the Odessa variety, proved unstable. The number of plants bearing dense heads was 71, as opposed to 16 for the looser ones.

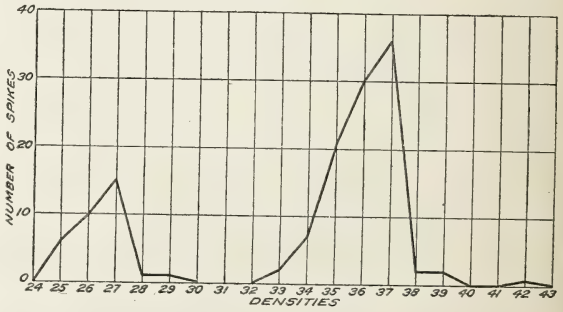

FIG. 15.—Curve showing the density of 134 spikes of Odessa (No. 9) barley grown at St. Paul, Minn., in 1913.

While a character need not be invariable under all conditions in order to be useful, a test was made to discover the effect of soil and climate on density of spike. Six selections were planted at St. Paul, Minn., at Chico, Cal., and at Aberdeen, Idaho. At Aberdeen they were grown both under irrigation and upon dry land. The measure-

ments at St. Paul and at Aberdeen were made by the writer, while those at Chico were made by Mr. E. L. Adams. The result is shown in figure 16. As a whole the variations were parallel, Nos. 6 and 35 being strikingly so. The four less dense selections showed an extreme variation of only three units, while the two dense selections varied much more. In No. 32 this was due in part to poorly developed heads; at St. Paul, particularly, its spikes were so short that it was impossible to find many in which five successive nodes bore fertile florets. The effect of sterility is to lengthen the internode of the rachis. All types were most dense at Chico and least dense at St. Paul. The effect of irrigation as shown at Aberdeen was very slight, especially when compared with the effect of the combined factors of geographical location.

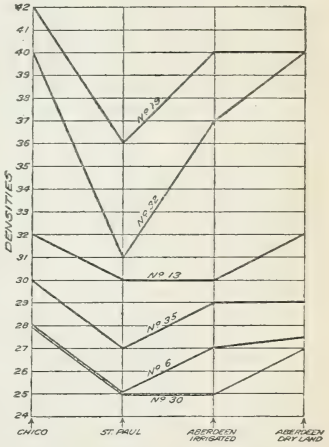

FIG. 16.—Curves showing the average density of six selections of barley grown at Chico, Cal., at St. Paul, Minn., and on irrigated and unirrigated land at Aberdeen, Idaho.

The character of the curves was influenced even less than their relative density. Table V shows the distribution into their various densities of 100 spikes from each of 59 plats of barley. By referring to Table V it will be seen that some selections always present a much sharper curve than others, and thus afford opportunity for varietal distinctions in the distribution of the measurements. Avoiding the extreme examples, it will be noted that the spike of No. 30, for instance, which has already been condensed three or four units by the use of the formula for density, is still less compact than No. 35, which by the same operation has been made to appear slightly less compact than it really is. At St. Paul, No. 35 has a total of 85 per cent of its spikes within three units in one instance and 91 per cent in another, while No. 30 has but 82 per cent within this limit. At Aberdeen, under irrigation, No. 35 has a total of 91 per cent of its spikes within three units, while No. 30 has but 78 per cent; upon the dry farm at the same place, No. 35 has a total of 81 per cent of its spikes within three units, while No. 30 has but 77 per cent; and at Chico, No. 35 has 94 per cent of its spikes within three units, while No. 30 has 91 per cent.

TABLE V.—*Distribution into their various densities of 100 spikes from each of 59 plats of barley.*[1]

Place and name.	Stock No.	Row No.	Number of internodes in one decimeter.																																	
			21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46								
St. Paul, Minn.:																																				
Manchuria	11	17			6	33	54	6	1																											
Servian	34	29					15	24	39	9	2																									
Eagle	13	31								3	22	39	27	9																						
Sandrel	35	33				3	27	35	29	6																										
Malting	73	67					1	4	30	33	20	9	3																							
Odessa	9	23					6	10	15	1	1				2	7	21	30	36	2	2		1													
Mariout	32	25							1	3	7	16	31	24	11	5	1	1																		
Steigum	24	32				3	15	23	39	8	2																									
Oderbrucker	75	69						4	19	32	33	10	2																							
Meyer	77	71							3	14	36	32	13	2																						
Lake City	99	96			1	10	35	34	19	1																										
Triangular	96	93							1	18	47	26	5	3																						
Silver King	89	83								4	20	41	26	9																						
Sandrel	35	87					12	34	42	9	2	1																								
Odessa	94	89					8	28	49	11	4																									
Mahrische	72	66				2	12	34	32	14	6																									
Luth	103	100				1	13	32	47	5	2																									
Lake City	100	97			1	11	35	36	15	1	1																									
Summit	8	41								1	2	11	27	22	20	13	4																			
Odessa	97	94		1	10	37	39	11	2																											
Hanna	60	54	14	16	35	28	6	1																												
Do	23	30					17	27	31	14	9	2																								
Featherston	101	98					2	2	34	40	18	4																								
Meyer	51	45						2	19	34	34	10	1																							
Triangular	102	99					1	3	31	37	21	7																								
Luth	5	39							2	17	40	28	10	3																						
Meyer	3	91		3	8	23	54	10	2																											
Odessa	31	21					8	25	44	12	8	2	1																							
Svanhals	19	22												1	1	9	23	35	24	4	3														
Featherston	6	14			1	15	45	25	13	1																										
Odessa	93	88								2	6	19	28	31	10	3	1																			
Featherston	55	49		2	5	16	37	24	13	2	1																									
Italian	30	42		6	15	26	41	10	1		1																									
Minnesota No. 105	67	61					3	11	30	26	21	6	1		1	1																				
Chevalier	56	50		1	6	15	41	23	12	2																										
Luth	57	51		1	4	13	44	20	17	1																										
Hannchen	54	52						1	12	27	42	13	3	2																						
Excelsior, Minn.:																																				
Manchuria	(2)	A			1	3	15	19	17	12	10	7	10	6																						
Do	(2)	B			1	3	26	30	25	9	5	1																								
Do	(2)	C				1	33	32	29	4	1																									
Do	(2)	D				2	12	21	30	13	13	3	2	2	1	1																			
Chico, Cal.:																																				
Italian	30	25						3	24	37	30	6																								
Mariout	32	28																1	3	7	10	24	13	13	10	10	5	4							
Eagle	13	31										1	10	39	24	16	9	1																	
Svanhals	19	15																				18	22	34	12	13	1								
Sandrel	35	32									9	51	34	6																					
Featherston	6	14						7	35	39	18	1																								
Aberdeen, Idaho:																																				
Featherston	6	79					3	11	37	31	11	6	1																								
Mariout	32	100										1	8	6	11	14	9	20	8	12	9	1	1												
Eagle	13	103						1	1	8	26	30	21	10	2																					
Svanhals	19	26												1		2	4	23	12	18	24	6	9		1										
Italian	30	37		3	8	20	34	24	10	1																										
Sandrel	35	74						1	5	24	47	20	3																							
Featherston	6	379					2	9	31	30	18	5	1																							
Sandrel	35	374						1	11	20	34	24	6	1																						
Italian	30	337		3	3	2	12	30	34	13	3																									
Svanhals	19	326													1	1	5	6	18	14	21	28	2	4										
Mariout	32	400														1	2	4	19	9	14	21	9	13	4	4								
Eagle	13	403								1	5	12	24	45	10	3																				

[1] Featherston, Luth, and Meyer are all Manchuria or Oderbrucker barleys, named from the farms upon which the selections were made. Measurements of 134 instead of 100 spikes are given in Odessa No. 9, which broke up into two types. The Excelsior barleys were from general fields, three of which were unpedigreed. At Aberdeen, rows 26 to 103 were irrigated, while rows 326 to 403 were grown upon dry land. The irregularity in Mariout is largely due to imperfect spikes.

[2] Field.

FERTILITY.

The variation in fertility is the most evident and the most vital of all the modifications that occur in barley. At each node of the rachis a group of three single-flowered spikelets is produced. In the 6-rowed barleys, each of these develops a separate kernel. As the groups of spikelets are placed alternately on opposite sides of the rachis the result is six columns of kernels from the base to the tip of the spike. In the 2-rowed barleys, only the central spikelet at each node is fertile, and therefore there are but two columns of grains. This reduction does not take place by the elimination of the outer spikelets but by their sterility. The median floret of each set of three accomplishes its normal development, while on either side are the small, undeveloped, infertile florets. However, the sexual organs have not disappeared. The three stamens reach an appreciable size and the ovary, though rudimentary in some ways, persists even to the plumose stigma. In one group of the 2-rowed barleys there is a still further modification of the lateral florets. In Abyssinian barleys there is a considerable number of forms in which the lateral spikelets are rudimentary; that is, they no longer contain even infertile flowers, the whole spikelet being reduced to structures that are little more than hairlike.

In the experience of the writer these well-known taxonomic divisions have proved entirely stable. The observations have included hundreds of varieties, and these varieties have been grown under such varying conditions as to stimulate monstrous developments in many structures, but in no case has there been indication of bridging over these separations. It is the opinion of the writer that the numerous instances of exceptions recorded have been misinterpreted. The one cited by Körnicke (15) was most probably a cross, as the variation of the progeny was such as is always secured by hybridization. The more common exceptions usually described are the occurrence of 3-rowed and 8-rowed freaks, and 2-rowed barleys in which some of the lateral florets are fertile. All three exceptions are probably due to the formation of adventitious spikelets. Such spikelets are common, and if several of them occur along one side of the rachis of a 2-rowed barley the result is a 3-rowed spike. If a duplication of the groups of spikelets at the nodes of one side of the rachis occurs in a 6-rowed barley, the result is nine rows, which, if imperfect in any way, are easily mistaken for eight. It is entirely possible that florets of lateral spikelets of 2-rowed varieties are sometimes fertile, but in practically all of the numerous cases that have been noted by the writer a close inspection of such grains has shown them to be adventitious, with the sterile floret also present.

Aside from the observations upon established forms, it has been the fortune of the writer to isolate a number of which there seem to be no published descriptions. These all came from Abyssinian barleys, and, as the work is not yet completed, only a general indication of the results need be given here. The group of 2-rowed barleys with rudimentary florets seems much larger than has been previously thought. They vary from the wide zeocrithonlike types to narrow nutanslike forms and through a series of colors and combinations of colors. In barleys received from the same region there is a group with a curious irregular, yet heritable, habit of floret abortion. In the ripened spike the spikelets are normal at the base and for a varying distance toward the tip. The upper portion usually reduces suddenly to a 2-rowed form. In this case the lateral spikelets are not merely sterile, but are reduced to only the outer glumes and the rachilla, the floret having disappeared entirely. The spikes are found to present these modifications even when the head first emerges from the boot. The actual time of the reduction has not been determined, but it is so early that no scar is present, indicating that the floret never started to develop.

THE EMPTY, OR OUTER, GLUMES.

The outer glumes present but two phases. They are usually narrowly lanceolate, but in rare forms are ovate lanceolate. In the latter case they generally bear moderately long awns. A few intermediates are formed by combinations in which only certain ones instead of all the normal outer glumes are replaced by ovate-lanceolate ones. In this investigation, while numerous ovate-lanceolate selections have been made, there has been nothing added to the information already at hand.

THE FLOWERING GLUMES.

Two of the variable features of the flowering glume are treated elsewhere. The toothing of the nerves is considered with the rest of the Svalof system under a later heading. The color of the glumes is taken up with the color of the other plant organs in the general discussion of pigmentation. Most of the remaining variable points of structure in the flowering glume are to be found in its terminal appendages, which are usually awns, but may be trifurcate hoods, in the nature of its base, and in its adherence or nonadherence to the pericarp.

AWNS.

The dimensions of the awns are naturally their most apparent variable features. There are marked varietal differences in both length and breadth of awns, but, unfortunately, they are so corre-

lated with the taxonomic groups as to make them of slight use in separating nearly related strains. All the Hanna barleys have long, narrow awns; the *zeocrithon* and *hexastichum* forms have short, rather broad awns and the naked barleys excessively broad ones. In the Manchuria group there is some suggestive variation, but it needs the support of other variants to become convincing.

There is, in addition to these rather narrow variations, a still greater difference in length of awn. In these cases an abrupt and conspicuous reduction takes place. There are botanical varieties characterized by very short awns and others in which the glume is merely pointed. Derr (12) secured such a form through crossing. Such variations make a very decided separation from their long-awned relatives.

The toothing of the awn is subject to many variations, some of which are constant. The distinctions are often merely those of degree. There are forms, especially in the *hexastichum* and *zeocrithon* groups, in which the toothing is very profuse and the individual teeth very large. These characters are constant and are inherited, with no more tendency to variation than are other vegetative characters. In the Manchuria-Oderbrucker barley the teeth are numerous, but only average in size, being much smaller than the ones referred to above. The 2-rowed barleys of the Hanna type have fewer and very much smaller teeth than the Manchuria. In still other barleys the awns are smooth. In 1910 the writer isolated from a mixed Hanna barley a form in which the awn was smooth, except for a few small teeth at the tip. In 1911 two plants were secured from an English importation of a seldom-cultivated botanical variety in which the awns are absolutely smooth. Hybrids of this selection upon Manchuria and Bay Brewing sorts show the toothing to be dominant over the absence of teeth. In the second generation smooth awns again appeared. Regel (22) and others have reported a considerable number of such barleys.

Although it seems not to have been used by systematists, the rigidity of the awn has been found to be serviceable in varietal descriptions. From most barleys it is broken rather easily in thrashing, but there are some which will not thrash clean, no matter how much effort be expended. This character is commonly recognized in the California barley, but exists in Mariout, in some of the selections from Odessa, and in numerous others as well. These varieties have been grown at a large number of points and show no inconstancy in this character.

There is also a difference in the persistence of the awns. There are a few varieties that are almost deciduous. The Primus, for instance, has been observed in a great variety of locations, and it always drops a large percentage of its awns as it ripens. The loss of the awn in

such varieties does not come about through the breaking of that organ, but by its being loosened from the glume. It is the tissues of the glume that give way, and lack of persistence is thus in reality a character of that organ.

In the hooded barleys the awn of the flowering glume is replaced by a trifurcate appendage. This is of evident monstrous origin and is connected with the awned class by no true intermediates. The exact nature of the appendage is not clear. In structure the parts appear to be the result of vegetative stimulation, and they are glume-like in appearance. The fact that they are three in number and that they bear rudimentary florets indicates that they are a partial repetition of the spikelets of an internode, the leafy segments being the flowering glumes. The character is absolutely constant.

THE BASE OF THE FLOWERING GLUME.

The method of the attachment of the lemma, or flowering glume, to the rachis has been shown by Atterberg (1) to be a distinguishing mark between the *erectum* and *nutans* groups. In the *nutans* group the grain (and therefore the flowering glume) is attached by a very constricted band of tissue which, when separated, leaves the proximal extremity smooth. The surface is oblique to the long axis of the grain and presents a small horseshoe-shaped depression just above the line of attachment. In the *erectum* group there is more than one variation of form, but all are centered around an attachment to the rachis that is much broader than in *nutans* and the depression is absent. When the central nerve of the dorsal glume is not too large and continued too far through the base, a transverse crease is found just above the attachment. The 6-rowed barleys are separated by the same means.

ADHERENCE OF THE FLOWERING GLUME TO THE PERICARP.

The normal form of barley is one in which the glumes are grown fast to the pericarp. There are numerous varieties in which this union does not occur. These constitute our naked barleys. Both forms are absolutely stable. The character offers no opportunity for minor distinctions, unless it be in such cases as Princess, which the Swedish Plant-Breeding Association maintains has a low weight per bushel, owing to an abnormally loose attachment of the glumes.

THE SVALOF CHARACTERS.

In 1889, Neergaard (19), of the Swedish Plant-Breeding Association at Svalof, announced the most important discovery in the classification of the lesser groups of barley that has ever been brought to the attention of the world. Not only was it of exceptional intrinsic value, but it acted as a great stimulus in the study of elementary

forms and has been the cause of much of the progress that has been made in the isolation of biotypes.

Neergaard's work was based upon the careful study of the spike. He discovered that two previously unobserved variants were dependable morphological distinctions. These were the nature of the covering of the basal bristle and the toothing of the inner pair of dorsal nerves. The basal bristle, which is the continuation of the rachilla of the spikelet, is clasped within the folds of the glumes and is carried with the kernel when it is removed from the spike in the process of thrashing. The bristle is covered in some cases with long, stiff hairs; in others, with short, curly ones. The inner pair of nerves upon the dorsal surface of the grain are in some cases provided with numerous, small, translucent teeth; in others they are smooth.

The use of these two new characters gave four separations in any group, i. e., long-haired bristle and nerves without teeth, long-haired bristle and nerves with teeth, short-haired bristle and nerves without teeth, and short-haired bristle and nerves with teeth. When these separations were applied to the larger groups, *Hordeum sativum erectum*, *Hordeum sativum nutans*, and *Hordeum sativum vulgare* (*tetrastichum*), 12 smaller groups resulted.

Although this new grouping was only a small part of the Svalof observations on barley, it soon became known as the Svalof system, due no doubt to its novelty. As a new departure it has been subject to much more controversy than have most of the older and universally accepted taxonomic features. Several breeders, among whom Broili (10) is the most notable, have attacked the system and declared that, though the characters might be trustworthy at Svalof, when the plants were grown under other conditions they did not remain constant. Tschermak (13, p. 286), Blaringhem (7), and others, have supported the investigators at Svalof in the matter of the basal bristle, but have not committed themselves so completely with reference to the toothing of the nerves. Since the point of contention is the effect of soil and climate, observations in this country are of many times the natural value of those in Europe. The variation between California and Minnesota or Idaho and Virginia represents a range that is impossible to a European breeder.

Observations have been made upon some hundreds of selections representing all botanical groups. Very little variation was found in the nature of the rachilla. All observations tend to credit this character with as much stability as is usually found in taxonomic work. As would naturally be expected, the toothing of the dorsal nerves has been found to be more variable and more influenced by climate. The rachilla is the axis of the spikelet, a definite and vital portion of the fruiting body. The teeth on the dorsal nerves are of

no vital significance, being mere manifestations of the epidermis. The writer feels that the Svalof position has here been injured by a defense that is too enthusiastic. The fact that variations may or may not occur in a strain is of little importance if the limits are definable. No doubt there is variation, and it is especially noticeable in the sparsely toothed varieties. A cactus under proper conditions will display leaves, yet no one will question the propriety of describing the cacti as leafless plants. They never become foliage plants, and no more do we expect a smooth-nerved Hanna selection to show the strong toothing of the Manchuria. It may at times present a few scattering teeth, but it would never become even moderately strongly toothed, and certainly there are strongly toothed sorts that are never anything else.

VARIATIONS IN THE KERNEL.

The kernel itself varies in many ways. The more definite variations not treated elsewhere are shape, dimensions, weight, and composition.

SHAPE OF KERNEL.

The shape of kernel is well established as a group distinction and is often a varietal characteristic. The 6-rowed varieties are sharply set off from the 2-rowed ones by the twisting of the lateral kernels. Even the central kernel of the 6-rowed varieties, although it is not twisted as are the lateral ones, is still of a shape different from that of the 2-rowed sorts. In the 6-rowed varieties the greatest diameter is nearer the distal end of the grain, while in the 2-rowed ones it is nearer the proximal end.

Within the groups the separations are naturally less marked. Certain Finnish and Russian barleys may readily be distinguished from the Manchuria because of their being less nearly oval in shape. The extremities of the grain are more pointed, giving a fusiform, or spindle-shaped, seed. The Goldthorpe barleys, especially such extreme types as Standwell, are readily separated from the other 2-rowed forms. The Swedish Plant-Breeding Association reports that Hannchen and Princess can be readily distinguished in bulk samples by the shape of the kernel. Most of the distinctions, however, are so dependent upon the relative proportions of the grain that it is impossible to consider shape independent of dimensions.

THE DIMENSIONS OF THE KERNEL.

The barley kernel varies in length, width, and thickness. At times one or all of these may constitute a varietal character. No other barley could be confused with the Smyrna. Its long grain is unique. It is also very doubtful whether a second strain could be found that possesses the unusual breadth of the Standwell. In all but these

very extreme types the use of these variants must rest upon statistical methods.

At any place, the product of a variety in the same season is sufficiently uniform to give a decided indication of the average size of the kernel with 100 measurements. The size of the kernel is, however, but partially dependent on variety. Table VI gives a summary of measurements made upon samples of grain of three varieties of barley grown at various points in the United States. In this table the columns marked "Greatest" and "Least" have very little significance, but the averages are quite instructive. The variation is remarkably uniform. The length and the lateral and dorso-ventral diameters of Princess each differ about 0.5 of a millimeter in the averages, while the dimensions of Primus each vary 0.4 mm. and those of Chevalier II 0.2 mm. It does not necessarily follow that Princess is the most variable of the three. This variety was subjected to more extreme conditions than the other two, and in two locations the development was hardly normal.

TABLE VI.—*Dimension measurements (in millimeters) of 100 kernels of each of three varieties of barley.*

Variety and place of production.	Length.			Lateral diameter.			Dorso-ventral diameter.		
	Greatest.	Least.	Average.	Greatest.	Least.	Average.	Greatest.	Least.	Average.
Princess:									
Huntley, Mont. (irrigated)	10.0	9.0	9.3	3.8	3.3	3.6	3.0	2.2	2.7
Huntley, Mont. (dry land)	9.9	8.7	9.2	3.4	3.0	3.2	2.5	2.0	2.2
McPherson, Kans	9.6	8.8	9.2	3.7	3.1	3.3	2.9	2.2	2.5
Plainfield, Cal	10.2	9.0	9.5	4.0	3.3	3.7	2.9	2.3	2.6
Morris, Minn	9.6	8.7	9.1	3.7	3.0	3.4	2.5	2.0	2.3
Primus:									
Svalof, Sweden	10.1	9.1	9.6	4.2	3.4	3.8	3.3	2.5	2.9
St. Paul, Minn	10.4	8.7	9.6	3.9	3.4	3.7	3.0	2.5	2.8
Bonsall, Cal	9.8	9.0	9.5	3.8	3.2	3.6	3.2	2.6	2.8
Amarillo, Tex	10.0	8.9	9.6	3.7	2.9	3.4	2.6	2.2	2.5
Milwaukee, Wis	10.5	9.6	9.9	4.0	3.4	3.8	2.8	2.4	2.6
Fort Atkinson, Wis	10.4	9.0	9.8	3.9	3.4	3.7	3.0	2.4	2.8
Chevalier II:									
Warren, Minn	10.0	8.3	9.4	3.8	3.1	3.6	2.9	2.2	2.6
Flandreau, N. Dak	10.0	9.0	9.6	3.7	3.1	3.5	2.8	2.2	2.6
Erie, Pa	9.8	8.8	9.4	4.0	3.2	3.6	3.2	2.5	2.8
Plainfield, Cal	10.0	8.2	9.4	4.0	3.3	3.7	3.1	2.5	2.8
St. Paul, Minn	10.2	8.3	9.5	3.8	3.0	3.5	3.0	2.1	2.6
Milwaukee, Wis	10.4	8.4	9.6	4.0	3.2	3.6	3.0	2.3	2.7

Of the three measurements, that of length is obviously the most dependable. The actual variation is no greater, and since it is based upon a much larger figure it is relatively less. Also, the two diameters are more affected by ripening conditions than is the length and are therefore less serviceable for local distinctions. The length seems to be determined by varietal and climatic influences early in the life of the plant, while the diameters are dependent upon the quantity of starch infiltration at ripening time. This is well illustrated in the two samples of Princess from Huntley, Mont., one of which was grown by irrigation and one on dry land. The length of the kernels

in the two samples was practically identical, while the diameters showed the greatest variations found within a variety.

The weakness of all grain measurements is not in the variation but in the fact that the interval between varieties is not great. The total range of averages is not large, and while many selections may be distinguished, a great many more must remain inseparable because of identical or nearly identical dimensions.

WEIGHT OF THE KERNEL.

The weight of 1,000 kernels is a determination that has been considered indispensable in the appraisement of exhibition samples, and it is also a very useful record in plant breeding. From the nature of this factor it is to be expected that it will vary with conditions and culture, but usually the variations are more or less parallel. In this investigation certain varieties have always been found relatively high and others relatively low in kernel weight, regardless of location or season. The character is, however, a varietal one and not often useful in separating related strains.

COMPOSITION OF THE KERNEL.

The varietal character of any barley, as far as composition is concerned, is subservient to climatic conditions. For example, if it is grown in California it will be much lower in nitrogen than if grown in Minnesota. The average differences in the composition of all varieties grown at two places is often greater than that between the two most extreme varieties at either place. Despite this fact, there is an actual varietal tendency. The Svanhals is reported in Sweden to be relatively high in nitrogen for a 2-rowed barley, and it is also high in this country. Analyses of samples of California feed from many States in the West and in the Plains area showed that this variety was always lower in nitrogen than other 6-rowed forms. Le Clerc and Wahl (17) found that the average protein content for Bay Brewing from all points was 10.73 per cent, while for the ordinary 6-rowed variety it was 11.86 per cent.

It is doubtful whether a factor with such wide and easily influenced limits can be made to be of assistance in the separation of strains, save in exceptional cases. It can, however, be used in the description of varieties, and may be of much importance in the selection of sorts adapted to satisfy market demands.

PIGMENTATION.

Color is one of the most easily determined characters of barley, but, unfortunately, it is also one of the most treacherous distinctions. The occurrence of pigments in certain cases and in certain tissues is undoubtedly hereditary and is transmitted unfailingly from genera-

tion to generation. In other cases the color appears intermittently or sporadically in strains and tissues ordinarily free from pigments. This erratic behavior, coupled with the fact that white, brown, black, violet, purple, amber, and blue-gray have been used in various classifications, led the writer to make a study of the pigmentation of barley. Since the colors in the seed seemed to be more numerous and less variable than in the other parts of the plant, the grain was used as the basis for the investigation.

The technic was adapted from that used by Mann (18) in his identification and location of the pigments in the cowpea. The grains were first examined by sectioning them dry. This avoided any modification such as might easily come from the action of solvents in an embedding process, or even from water if a freezing method were used. The hand sections were equally as satisfactory as those made with a microtome, as the areas in question were readily defined and the colors more easily seen in moderately thick sections than in very thin ones. The reagents most extensively employed were caustic potash, hydrochloric acid, and chloral hydrate. The sections were placed dry upon a microscope slide underneath a seven-eighths-inch cover glass, held in place by a drop of paraffin on either side. The reagents were drawn beneath the cover glass by means of blotting paper and their action watched through the microscope. Two per cent solutions of the acid and of the alkali and a saturated aqueous solution of chloral hydrate were used in these tests. If the pigment showed no change within a few minutes, the reagents were allowed to remain upon the section for some hours. In such cases, larger pieces were also placed in small vials containing 15 per cent solutions and examined at the end of 24 hours.

It soon became apparent that there were two pigments in barley. One was readily affected by the weak solutions, and from the nature of its reaction was undoubtedly anthocyanin, which occurs widely in the plant kingdom in both its red, or acid, and its blue, or alkaline, form. The other resisted even prolonged soaking in the more concentrated solutions and was probably a melaninlike substance.

The first varieties studied were those in which the adhering glumes were black. No change was effected by either the weak reagents or the prolonged soaking in concentrated solutions. The black did indeed become a brown, but this was most probably due to the distention of the pigment-containing tissues attendant upon the absorption of water. As a considerable number of varieties with black glumes were tested and as the results were uniformly the same, it would seem that a black or brown pigment in the glumes may be attributed to a melaninlike compound.

A number of Abyssinian varieties with purple glumes were sectioned and treated with the reagents. The purple color responded

at once to weak solutions. It immediately became blue when treated with the alkali and became red again when the acid was applied. The chloral-hydrate test here and in all other instances was less definite than in the case with most anthocyanin deposits. Upon its application the red color faded very slowly, until the natural yellow of the glumes became apparent. The red immediately returned when acid was added. There is no reasonable doubt that the color in these barleys is due to anthocyanin.

A naked barley with a violet or purple pericarp was examined. This color was also readily demonstrated to be anthocyanin. In this instance, as in some others, the pigment was found both in the pericarp and in the aleurone layer. In the former tissue it was red and in the latter blue. When treated with acid the red was unchanged, of course, while the blue also became red, greatly intensifying the effect.

In all barleys studied the anthocyanin was always red in the pericarp and glumes and always blue in the aleurone layer. In other words, the resting condition of the protoplasm was alkaline, while the inert tissue seemed to be in an acid condition.

A new form of naked barley isolated from an Abyssinian importation gave striking testimony of the taxonomic value of the distinction between the two pigments. This selection has a dense black pericarp. It was absolutely resistant to all concentrations of reagents, showing the pigment to be melaninlike. As far as the writer can learn, there is no other naked barley of the *nutans* group in which this pigment occurs, and this botanical form has no published description.

The last variety studied was *Hordeum vulgare pallidum coerulescens*. This variety has the peculiar blue color well known upon the market in Californian, Chilean, and similar barleys. The color has been held to be variable by both grain dealers and scientists. Regel explains its lack of stability by calling it a hybrid form. Examination showed the color to be due to a deposit of anthocyanin in the aleurone layer. This layer was readily changed to red by the application of acid and was as readily made blue again by the use of alkali.

The stability of this and other forms was studied in the fields. Anthocyanin seems likely to be found in any plant and in any part of the plant. It seems to appear abnormally in cases of malnutrition and is very likely to occur in conductive tissues that are ceasing to be functional. It has, however, a normal phase in the grain. In certain naked forms its stability is unquestioned, and, to the writer's mind, its variability in *coerulescens* has been overestimated. The hybrid theory of Regel in regard to *coerulescens* becomes untenable when two pigments are admitted. If an intermediate, it could be so only between a white variety and a black one. This is evidently

impossible, because a cross between a form with a melaninlike pigment and one with no pigment could not result in one characterized by the production of anthocyanin. The widespread opinion of variability is possibly due to faulty observation. The deposit is in the aleurone layer, and the color is sometimes obscured by the glume. The weathering of this organ, especially in humid areas, greatly lessens its transparency. The aleurone layer is covered by both pericarp and hulls. The color must not only be pronounced to enable one to detect it from without, but the coverings must also be passably transparent. When ripening occurs in rainy weather this is not the case, and the hulls must be removed in order to make a trustworthy determination. Maltsters often speak of the blue grains that appear after steeping—that is, when the coverings have become transparent.

There is undoubtedly a difference in the quantity of the pigment deposited from year to year. Part of this may be due to the conditions of growth and part to the conditions of ripening. This pigment, like melanin, is formed during the later stages of growth. It may be that an abbreviation of the ripening period, due to heat or drought, would result in a reduction of pigment.

The inheritance of this character has been tested by observations upon several strains isolated from various barleys. These have been grown for several years and at a number of places, and in every instance the aleurone layer has retained a decided amount of blue color. The black colors have become more nearly brown in some places but have never disappeared. Blue-gray and violet-purple colors in naked barleys are due to blue anthocyanin in the aleurone layer combined with a pigment-free pericarp in the blue-gray and with a red anthocyanin deposit in the violet. Both are unquestionably inherited.

Minor phases of anthocyanin formation are found in the foliage of the plant, in the nerves of the glume, and in the awn. A red foliage, although found more commonly in some forms than others, may ordinarily be disregarded. In most cases it indicates malnutrition of some sort. In the nerves of the dorsal flowering glume it may be more valuable as a distinction. A great many barleys show this character to some extent. Even the Hanna races possess violet or purple nerves just before ripening. None, however, develop the color to the degree that is attained by some of the Russian and Asiatic forms. In the barley nursery there are several Russian selections in which the stripes along the nerves are so broad that the grains are almost red. The same is true of the strain known as Kashgar, which was imported from the region of that name in India.

With reference to the color of the awn, an apparent anomaly was noted in 1911. In a certain selection some spikes were observed in

which each awn was marked with two parallel stripes of red extending from its base to its tip, and other spikes in which the same stripes were deep purple. When examined in the laboratory, the color proved to be two bright-red stripes in the epidermis, below which were two chlorophyll-bearing parenchyma areas running the full length of the awn. As long as the chlorophyll was present the color effect was deep purple, but as soon as this disappeared it was light red.

SUMMARY.

While all lesser distinctions must be based upon the broader groups and no study of a cereal can omit its classification, the plant characters useful in taxonomic work and the ones most useful in plant breeding are far from being the same. Plant breeding is concerned with minute differences. The broad taxonomic divisions are serviceable only as groups. The problem of the nursery is not to separate a 6-rowed Manchuria from a 2-rowed Hanna barley, but to detect a variant in a plat of Manchuria.

Strains are often shown to be distinct in early growth by their rate of development. All barleys rush through the early stages very rapidly, and a selection that is one or two days earlier than a second is very dissimilar in appearance on a given date.

Leaf production is, in some ways, a varietal character. In some varieties the third leaf appears in three days after the second, while in others it occurs six days later. In the production of the fourth leaf even a greater range exists.

In some strains the first tiller appears decidedly later than the fourth leaf. In others it appears earlier. In some the tillers are all produced within a short time; in others the process is extended over several days.

The emergence of the awn is an extremely important note, as it occurs at a time in the life of the plant when such an observation is of great value. The development is usually normal at this time, as hot weather and drought have ordinarily not yet had any effect. The emergence of the awn has been found to be far more accurate and more easily obtained than the date of heading. The precocity of the strain at the time of the emergence of the awn is a heritable character.

The date of ripening is, unfortunately, often influenced by season and, while a valuable character, is less dependable than the emergence of the awns.

A comparison of the development during all stages serves to reveal many differences not apparent when each stage is taken separately.

The length of the culm is of use as a local breeding note, but the variations are not parallel when strains are planted in totally dif-

ferent areas. The diameter of the culm is not serviceable, because nearly related barleys have culms of approximately the same size. The thickness of the walls of the culm is a note with a large experimental error and therefore of questionable utility.

The degree of exsertion of the spike is sometimes a varietal character but is not often useful.

The number of culms per plant is to some extent a varietal character, but selections are so affected by season and location that it is very difficult to use. The width of the leaves is useful in group distinctions and sometimes in varietal separations. The length of the leaves is much less dependable, and is serviceable only in rather extreme types. The number of leaves varies with the groups, but usually closely related strains possess approximately the same number of leaves.

The density of the spike may easily be made the basis of many separations. Often varieties that show no other differences are widely dissimilar in density. The density of a selection varies somewhat with season and location, but the mean is always sharply defined and the fluctuations more or less parallel. In some strains all spikes conform closely to the mean; in others the range is greater. This seems to be a varietal character and is constant even when the plantings are made under widely varying climatic and soil conditions.

The established taxonomic groups based on relative fertility were found to be invariable under all extremes of American climate.

The natural varieties in the *deficiens* group of Abyssinian barleys seem more extensive than most classifications have indicated. From barleys of this same region a group with a peculiar habit of floret abortion has been isolated.

The length and the width of awns vary, but they are so correlated with other taxonomic characters that they are seldom useful in close separations.

The tenacity of the awn is frequently a varietal character unaffected by location or season.

The character of the basal bristle has been found to be stable under American conditions.

The toothing of the inner pair of dorsal nerves is much more variable, but the variation is usually within definable limits.

The length of the kernel, while influenced by climate, is a varietal character. The lateral and dorsoventral diameters of the kernel are varietal characters to some degree, but they are so influenced by conditions of growth as to become confusing in most instances.

The composition of the grain is a varietal character, but it is one dominated by climate.

There are two coloring materials in barley: One, anthocyanin, is red in its acid and blue in its alkaline condition; the other, a melanin-

like compound, is black. The pigments may occur in the hulls, the pericarp, the aleurone layer, and occasionally in the starch endosperm. The resulting colors of the grain are quite complicated. White denotes the absence of all pigment; a heavy deposit of the melaninlike compound in the hulls results in black; a light deposit, brown. Anthocyanin in the hulls results in a light violet-red. In naked forms the melaninlike compound in the pericarp results in a black kernel; anthocyanin produces a violet one. The acid condition of anthocyanin in the pericarp superimposed upon the alkaline condition in the aleurone layer gives the effect of a purple color, while a blue aleurone beneath a colorless pericarp is blue-gray. White hulls over a blue aleurone cause the grain to appear bluish or bluish gray. Black hulls over a blue aleurone give, of course, a black appearance. The anthocyanin is always violet in the hulls and in the pericarp, showing that these tissues are in an acid condition, and always blue in the aleurone layer, showing an alkaline condition. The occurrence of anthocyanin in the pericarp of hull-less barleys is more significant than its production in the aleurone layer.

BIBLIOGRAPHY.

1. Atterberg, Albert.
   1889. Die Erkennung der Haupt-Varietäten der Gerste in den Nordeuropäischen Saat- und Malzgersten. *In* Landw. Vers. Stat., Bd. 36, p. 23–27.
2. ———
   1899. Die Varietäten und Formen der Gerste. *In* Jour. Landw., Bd. 47, Heft 1, 1–44.
3. Beaven, E. S.
   1902. Varieties of barley. *In* Jour. Fed. Inst. Brewing, v. 8, no. 5, p. 542–593, 12 fig. Discussion, p. 594–600.
4. Biffen, R. H.
   1905. The inheritance of sterility in the barleys. *In* Jour. Agr. Sci., v. 1, pt. 2, p. 250–257, illus.
5. Blaringhem, Louis.
   1904. Le laboratoire d'essais de semences de Svalöf (Suède). *In* Bul. Mus. Hist. Nat. [Paris], no. 7, p. 514–519.
6. ———
   1905. La notion d'espèce . . . *In* Rev. Idées, ann. 2, no. 17, p. 362–380, 8 fig.
7. ———
   1908. La variation des formes végétales. *In* Rev. Gén. Bot., t. 20, no. 230, p. 49–66, 11 fig.
8. ———
   1910. Études sur l'Amélioration des Crus d'Orges de Brasserie. 288 p., 17 fig., 20 pl. Paris.
9. Brenchley, Winifred E.
   1912. The development of the grain of barley. *In* Ann. Bot., v. 26, no. 103, p. 903–928, 22 fig.
10. Broili, Josef.
    1906. Ueber die Unterscheidung der zweizeiligen Gerste—Hordeum distichum—am Korne . . . 60 p., 3 pl. Jena.
11. Brown, A. J.
    1900. Note on green-skinned light barley. *In* Jour. Fed. Inst. Brewing, v. 6, p. 480–483. Discussion, p. 483–488.
12. Derr, H. B.
    1910. A new awnless barley. *In* Science, n. s., v. 32, no. 823, p. 473–474, illus.
13. Fruwirth, Carl, Proskowetz, Emanuel von, Tschermak, Erich, and Briem, Hermann.
    1910. Die Züchtung der vier Hauptgetreidearten und der Zuckerrübe. 460 p., illus. Berlin. *See* Fruwirth, Carl. Die Züchtung der landwirtschaftlichen Kulturpflanzen, Aufl. 2, Bd. 4.
14. Johannsen, W. L.
    1884. Om Frøhviden og dens Udvikling hos Byg. *In* Meddel. Carlsberg Lab., Bd. 2, Hefte 3, p. 103–134, 3 pl.

15. KÖRNICKE, F. A.
1885. Die Arten und Varietäten des Getreides. 470 p., 10 pl. Berlin. *See his* Handbuch des Getreidebaues, v. 1.

16. KUDELKA, FELIX.
1875. Ueber die Entwickelung und den Bau der Frucht- und Samenschale unserer Cerealien. *In* Landw. Jahrb., Bd. 4, p. 461–478, pl. 5–6. Also reprinted.

17. LE CLERC, J. A., and WAHL, ROBERT.
1909. Chemical studies of American barleys and malts. U. S. Dept. Agr., Bur. Chem. Bul. 124, 75 p., 1 pl.

18. MANN, ALBERT.
1914. Coloration of the seed coat of cowpeas. *In* Jour. Agr. Research, v. 2, no. 1, p. 33–56, 2 fig., pl. 6.

19. NEERGAARD, T. B. VON.
1889. Bestämning af kornets varieteter och sorter efter på kärnorna befintliga kännetecken. *In* Allm. Svenska Utsädesför. Årsber., 1888, p. 54–61.

20. NEWMAN, L. H.
1912. Plant Breeding in Scandinavia. 193 p., 63 fig. Ottawa.

21. REGEL, ROBERT.
1906. Les Orges Cultivées de l'Empire Russe. 39 p. Milan.

22. ———
1908. Ĵačhmeni s glatskimi ostĵami. (Glattgrannige Gersten.) *In* Bul. Bur. Angew. Bot., Jahrg. 1, No. 1/2, p. 5–64, 84–85. (German translation, p. 64–85.)

23. ——— FLAKSBERGER, CONSTANTIN, and MALZEW, A. I.
1910. Bazhnĵeĭshĭĭa formy pshenits ĵačhmeneĭ i sornykh rasteniĭ Rossĭĭ (The most important forms of wheat, barley, and weed plants of Russia.) *In* Bul. Bur. Angew. Bot., Jahrg. 3, No. 6, p. 209–282. Also reprinted.

24. TEDIN, HANS.
1908. Ueber die Merkmale der zweizeiligen Gerste, ihre Konstanz und ihren systematischen Wert. *In* Deut. Landw. Presse, Jahrg. 35, No. 79, p. 831–832; No. 80, p. 841–842.

25. VOSS, A.
1885. Versuch einer neuen Systematik der Saatgerste. *In* Jour. Landw., Jahrg. 33, p. 271–282.

26. WHELDALE, M.
1911. On the formation of anthocyanin. *In* Jour. Genetics, v. 1, no. 2, p. 133–158.

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